ICP/EXT-04-00241

Fiscal Year 2003, OU 7-13/14 Advanced Tensiometer Monitoring Results from the Deep Vadose Zone at the Radioactive Waste Management Complex

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Bechtel BWXT Idaho, LLC

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Project No. 23378

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Prepared for the
U.S. Department of Energy
Assistant Secretary for Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-99ID13727

ABSTRACT

Fiscal Year (FY) 2003 data from 30 advanced tensiometers, located at depths ranging from 6.7–73.5 m below land surface, were evaluated for temporal water-potential trends. Addition of the FY 2003 data provides 3-1/2 years of continuous water-potential record in sedimentary interbeds and basalt in and around the Subsurface Disposal Area at the Idaho National Engineering and Environmental Laboratory. In FY 2003, water potentials in sedimentary interbeds and basalt ranged from near saturation (approximately -25 cm of water) to approximately -375 cm of water. In the near-surface basalts and sediments (less than 12 m below land surface), drying trends continued to be observed in response to the cumulative effect of less-than-average annual precipitation for the last 4 years (2000 through 2003). Water-potential data from 15 of the 24 deeper tensiometers (i.e., 17 m or greater) indicated little-to-no change in moisture in FY 2003, suggesting near steady-state conditions at those locations for the past 3-1/2 years. However, long-term wetting or drying trends continued to be recorded at nine of the 24 deeper locations. Two of these wells showed long-term wetting over the entire 3-1/2 years of record. All but one of the deep locations that exhibited long-term drying were located near the main drainage ditch through the Subsurface Disposal Area and appeared to be related to decreased infiltration in response to lower-than-normal precipitation over the last 4 years (2000 through 2003).

CONTENTS

FIGURES

TABLES

ACRONYMS

bls	below land surface
FY	fiscal year
INEEL	Idaho National Engineering and Environmental Laboratory
PVC	polyvinyl chloride
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area

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1. INTRODUCTION

Data from a network of advanced tensiometers, ranging in depth from 6.7–73.5 m below land surface (bls) beneath and adjacent to the Subsurface Disposal Area (SDA), continued to be collected during Fiscal Year (FY) 2003 to characterize deep moisture movement at the Radioactive Waste Management Complex (RWMC) of the Idaho National Engineering and Environmental Laboratory (INEEL) (see Figure 1). Monitoring was performed in support of the Comprehensive Environmental Response, Compensation and Liability Act (42 USC § 9601 et seq., 1980) remedial investigation and feasibility study decision process for Waste Area Group 7, Operable Unit 7-13/14 (Holdren et al. 2002), and supports the following objectives:

1. Provide in situ field data to augment, confirm, or change the current conceptual model of flow in the unsaturated zone beneath the RWMC

2. Provide field water-potential data for hydrologic flow-model calibration and prediction

3. Provide baseline water-potential data in vadose zone basalts and sedimentary interbeds in the RWMC area before remediation and closure of the SDA

4. Assess lateral movement of water from the spreading areas in conjunction with future tracer tests.

The past 3-1/2 years of data collection from the deep advanced tensiometers at the RWMC has provided field data to address the first three objectives. The fourth objective, to assess lateral movement of water from the spreading areas, cannot be fully addressed until flows in the Big Lost River require diversion of water to the spreading areas. However, data acquired by the deep advanced tensiometers do establish baseline conditions for later comparisons when water is diverted to the spreading areas.

Monitoring of the majority of the advanced tensiometer network in the deep vadose zone at the SDA was initiated in FY 2000, although data from several wells span a longer time (i.e., from 1996 to the present). Previous results from the advanced tensiometer monitoring in the deep vadose zone are presented in Sisson and Hubbell (1999), Hubbell et al. (2002), and McElroy and Hubbell (2001, 2003) and are summarized below.

Hubbell et al. (2002) documented monitoring of a nested series of tensiometers from 6.7–31.4 m bls at a single borehole (Well 76-5) in the SDA from 1996 through 2000. Based on 4 years of monitoring data, water potentials at this location were found to be generally constant, but were interrupted by an episodic recharge event that was tracked to the 17-m depth during the 1999 spring snowmelt.

McElroy and Hubbell (2003) evaluated water-potential data from the deep advanced tensiometer network at the SDA from spring 2000 through August 2002. Results indicated drying of the near-surface (above 17 m) basalts and sediments. These drying trends were presumed to be in response to the cumulative effect of less-than-average annual precipitation during the monitoring period. In the deeper

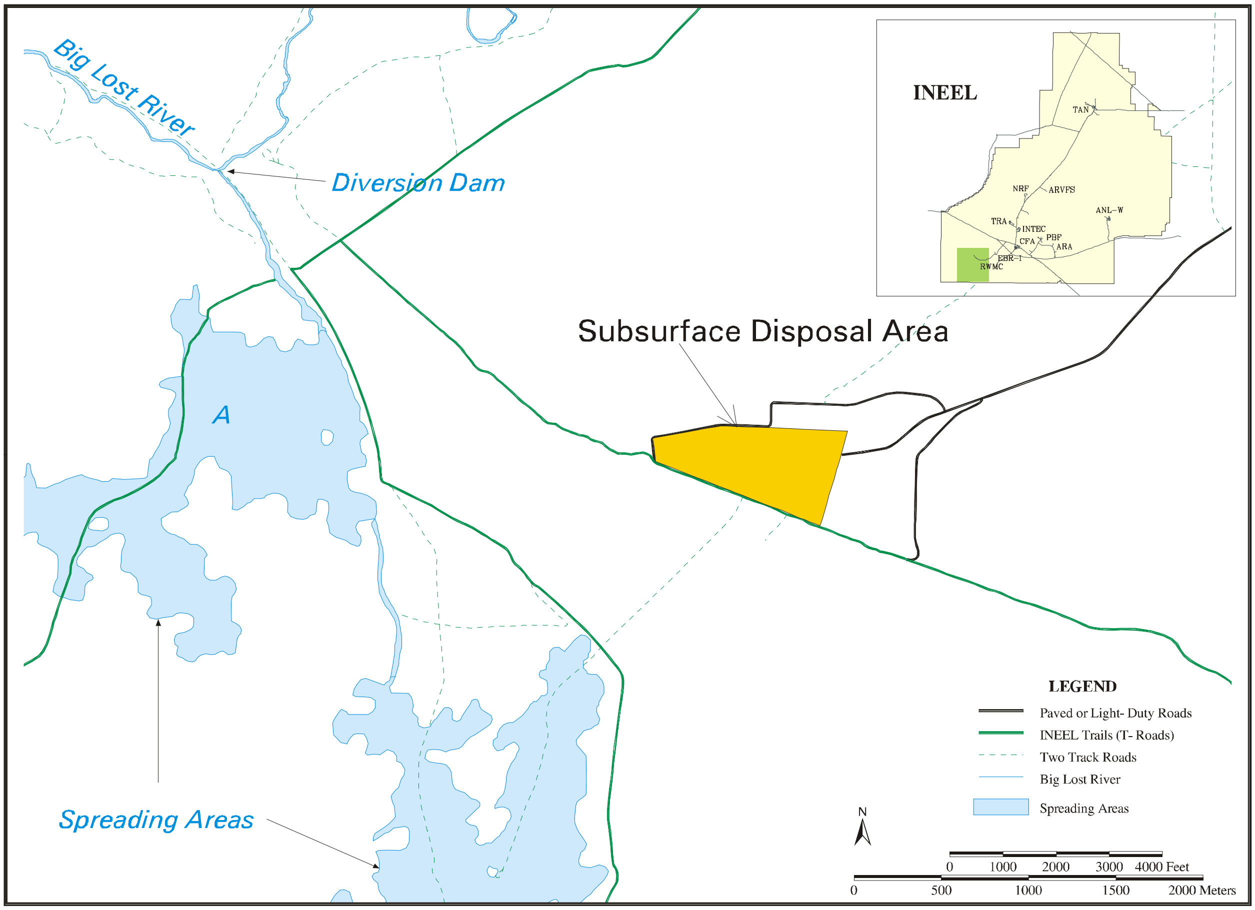


Figure 1. Location of Subsurface Disposal Area relative to the Idaho National Engineering and Environmental Laboratory, the Big Lost River, and the spreading areas.

basalts and sediments, steady-state conditions were observed at 15 of the 24 locations at or below 17 m (McElroy and Hubbell 2003). However, eight of these deep locations showed long-term drying and wetting trends, in contrast to the expectation of steady-state conditions at depth. Long-term drying, observed at seven of the eight trending sites, occurred at locations near the east-west drainage ditches. It was hypothesized that the subsurface beneath areas of focused infiltration (e.g., drainage ditches) were responding to decreased run-off from 3 years (2000 through 2002) of less-than-average precipitation. A continuous wetting trend over the 2-1/2-year monitoring period was recorded at one of the eight trending sites (i.e., Well O4) located outside of the SDA.

Based on averaged water potentials from the advanced tensiometers, McElroy and Hubbell (2003) concluded the subsurface to the BC sedimentary interbed depth (i.e., approximately 34 m bls) was wetter inside the SDA than outside the SDA. This was attributed to focused infiltration in low-lying areas (e.g., drainage ditches) or open pits and trenches that flooded in the past. Deep percolation of 1–32 cm/year was estimated from averaged water potentials using a unit gradient approach (McElroy and Hubbell 2003).

1.1 Scope

In this report, water-potential data collected from the deep tensiometer network during FY 2003 are added to the previously published data and evaluated. Evaluation will focus on temporal trends to determine whether previously identified moisture trends (McElroy and Hubbell 2003) continued during FY 2003.

1.2 Document Overview

Section 2 describes the RWMC and includes a geologic cross-section of the subsurface at the RWMC. Section 3 describes the advanced tensiometers and installation of advanced tensiometers in boreholes. Water-potential data from tensiometer monitoring through September 2003 are then presented and discussed in Section 4. Section 5 summarizes results and makes recommendations for future work. Section 6 lists the supporting references cited in this document.

2. SITE DESCRIPTION

The SDA is a 39-ha (97-acre) portion of the RWMC, located in the southwest portion of the INEEL, in southeastern Idaho (see Figure 1). Low-level, transuranic, and mixed waste was buried in shallow pits and trenches in the SDA from 1952 until 1970, when burial of the transuranic portion of the waste ceased. Since 1985, only low-level waste has been buried at the SDA. Contaminants of concern detected in the unsaturated zone beneath the SDA include nitrates, carbon tetrachloride, C-14, Tc-99, and uranium isotopes (Holdren et al. 2002).

The SDA is located on the Eastern Snake River Plain, an arcuate depression extending from Yellowstone Park and northwestern Wyoming westward across Idaho to the Oregon border. In the vicinity of the INEEL, the Eastern Snake River Plain has an approximate elevation of 1,500 m and is bounded by mountains and high plateaus on the north, east, and south. The Snake River Plain Aquifer underlies the SDA at a depth of approximately 177 m. The INEEL receives approximately 22 cm of precipitation annually based on a 38-year record (Clawson, Start, and Ricks 1989), and the majority of the November-to-April precipitation falls as snow. The region is classified as arid to semiarid.

2.1 Interbed Descriptions

The RWMC lies within a natural topographic depression. The subsurface beneath and adjacent to the SDA comprises a thin (0–7-m) cover of loess underlain by thick sequences of fractured basalt intercalated with thin sedimentary interbeds (see Figure 2). The upper 70 m of the subsurface is composed of three primary basalt flow groups called the A, B, and C basalts. Two laterally extensive sedimentary interbeds occur at 34 and 73 m bls and are named after the basalt flow groups between which they lie; the BC (at approximately 34 m) and the CD (at approximately 73 m) sedimentary interbeds. A less extensive, discontinuous sedimentary interbed is located at approximately 9 m bls and is referred to as the AB interbed. The thickness of the sedimentary interbeds varies from 0 to about 10 m.

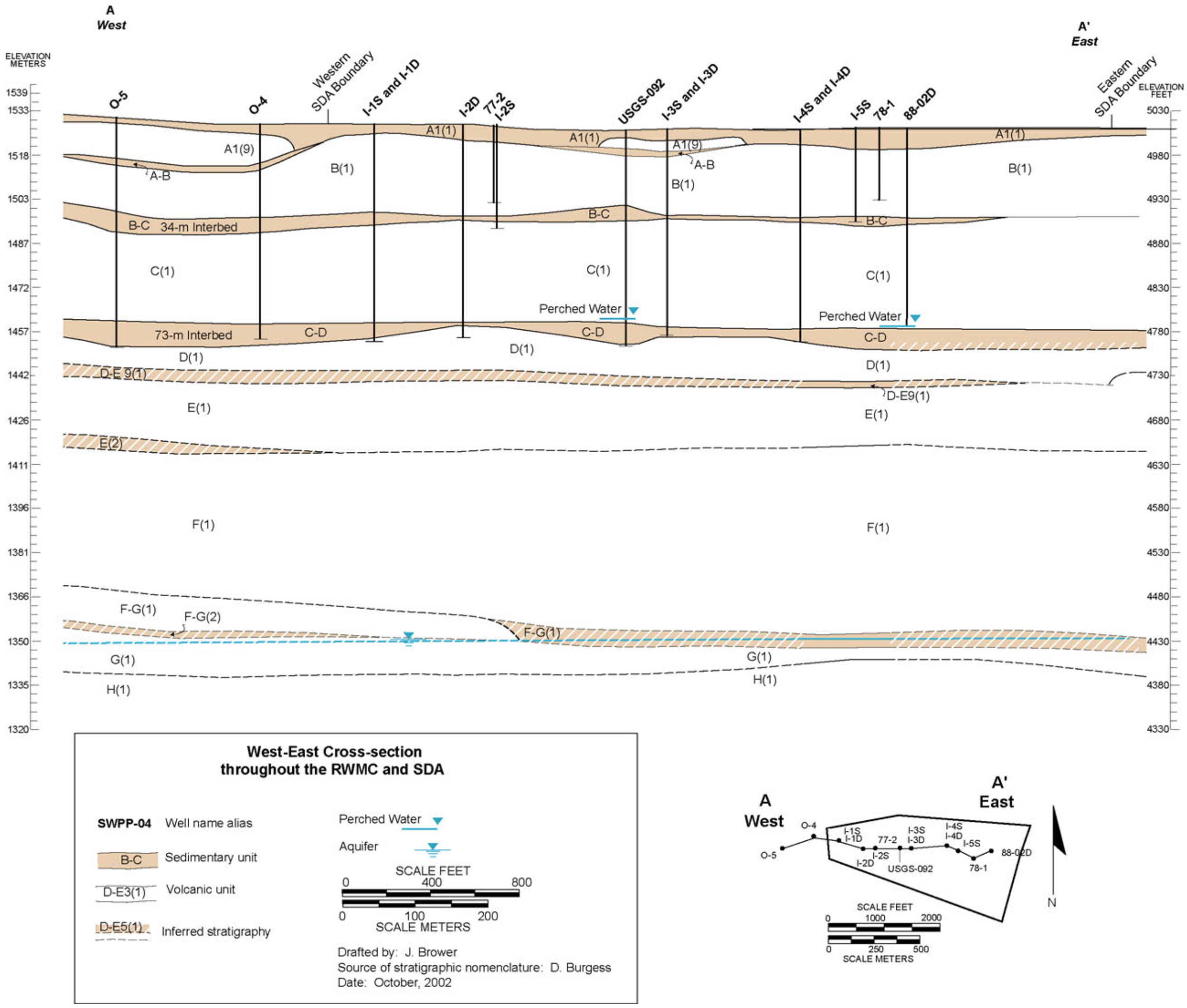


Figure 2. West to east trending cross-section through the Subsurface Disposal Area.

3. METHODS

Advanced tensiometers are instruments that yield water-potential data at any depth. Water potential is a means of measuring the relative energy state of water to evaluate the status and movement of water. Under fully saturated conditions, water is at hydrostatic pressures greater than atmospheric pressure and water potential can be considered positive. Under unsaturated conditions, capillary and adsorptive forces hold water in the porous medium. In this unsaturated state, water potential is considered to be negative, by convention, because the hydrostatic pressures are less than atmospheric pressures. The advanced tensiometer measurements are expressed in terms of an equivalent head of water (e.g., the centimeters of water units used) in this report.

The advanced tensiometer is composed of a porous cup (i.e., 1 bar, standard flow, ceramic, 50-60 ml volume) installed at a specified depth with an attached polyvinyl chloride (PVC) pipe (2.54 and 3.81 cm, Class 200) that extends to land surface (see Figure 3). A small (approximately 100 ml) volume of water is placed in the PVC pipe to fill the porous cup and create a small (a few centimeters) reservoir of water in the PVC pipe above the porous cup. A pressure transducer is placed inside the PVC pipe and seated just above the porous cup by means of a rubber stopper, sealing the water chamber in the porous

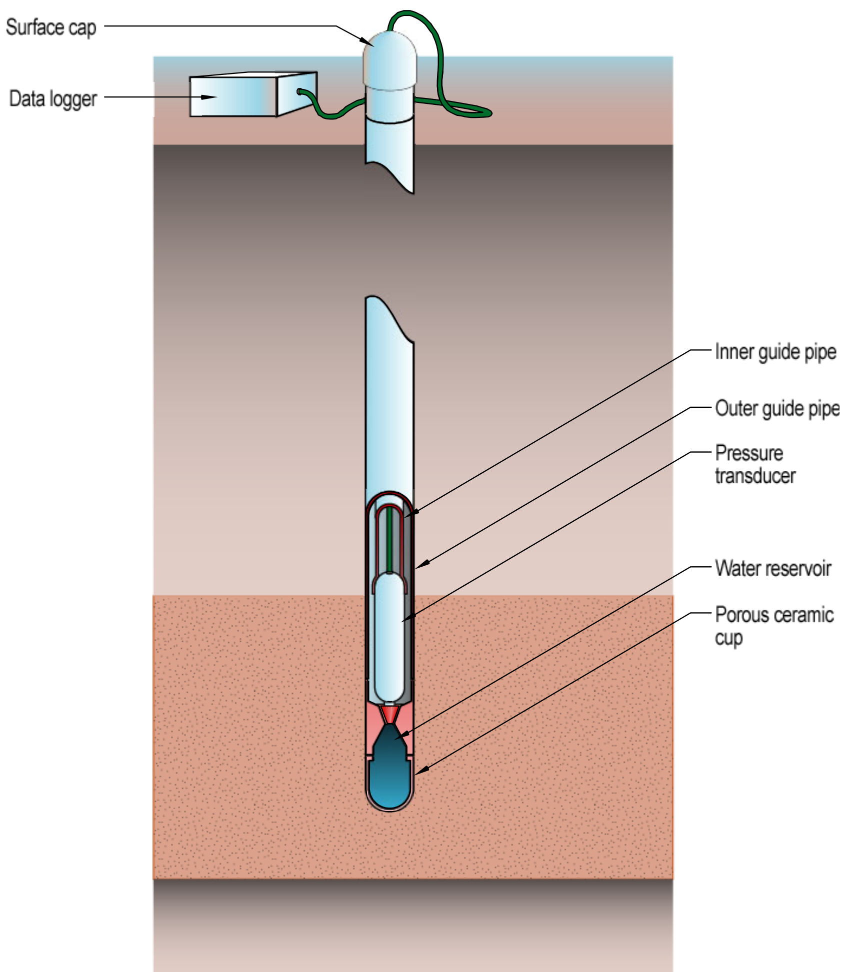


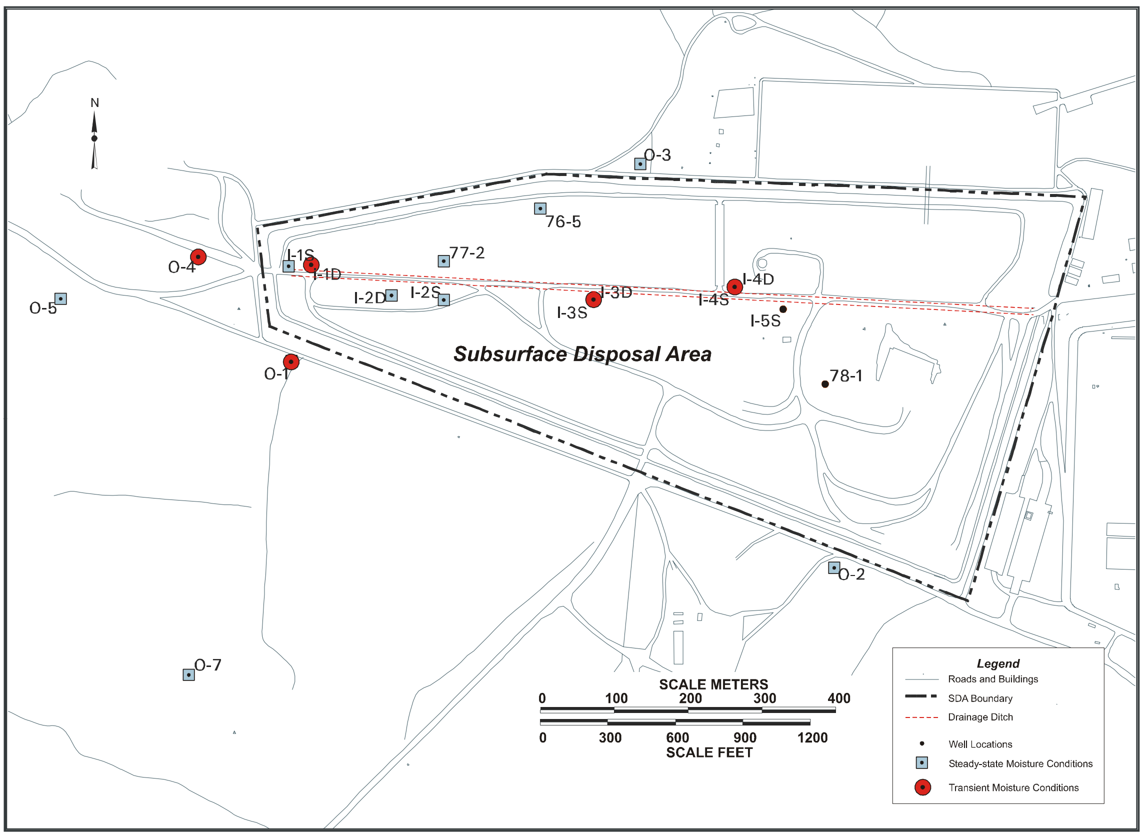
Figure 3. Schematic of advanced tensiometer showing porous cup, transducer, and outer polyvinyl chloride guide pipe.

cup from the upper reservoir of water in the PVC pipe. The water in the porous cup will move into or out of the formation until the partial vacuum in the cup is equal to the subatmospheric water pressure in the surrounding soil. The pressure transducer measurement of this partial vacuum is then considered equivalent to the soil-water potential.

The pressure transducers[a] were connected to Model 510X, 10X, or 23X Campbell data loggers or a Tumut Gadara data logger. This system collects continuous water-potential measurements at each instrumented depth. Data were collected at least every 4 hours, and data loggers were generally downloaded on a monthly basis. The pressure transducers were calibrated before installation, field checked periodically, recalibrated after field placement if measurements were questionable, and replaced as needed. Measurements presented in Section 4 were corrected for the pressure of a 12-cm hanging water column located above the pressure transducer.

3.1 Advanced Tensiometer Installation

Locations of wells containing the deep advanced tensiometers are shown in Figure 4. Tensiometer depths and adjacent lithology are listed in Table 1. Well number and depth (rounded off) (e.g., Well I1S-31 for the tensiometer at the 31.4-m depth in Well I-1S) will be used to identify



Blue highlighted squares = steady-state conditions
Red highlighted circles = long-term drying or wetting trends below depths of 17 m (except nested Well 76-5, represented by tensiometers below 18 m). Transient (red) wells tend to be located along the main east-west road through the center of the Subsurface Disposal Area.

Figure 4. Locations of wells with tensiometers.

a. Plus or minus 800 cm of water differential pressure relative to atmospheric.

Table 1. Well names, instrument depths below land surface, lithology adjacent to each instrument, and water potential measurements at 4:00 p.m. on February 16, 2003.

Well	Tensiometer Depth[a] (m [ft] bls)	Lithology at Depth of Tensiometer	Water Potential at 4:00 p.m. on February 16, 2003 (cm water)
I-1S	31.4 (103)	BC sedimentary interbed	-29.3
I-1D	69.2 (227)	CD sedimentary interbed	-371.6
I-2S	28.7 (94)	Unknown, no recovery and no gamma log	-105.7
I-2D	53.6 (176)	Basalt, massive	-77.5
I-2D	68.0 (223)	CD sedimentary interbed	-249.8
I-3S	28.3 (93)	BC sedimentary interbed	-66.3
I-3D	69.8 (229)	CD sedimentary interbed	-217.8
I-4S	29.7 (97.5)	Basalt/BC sedimentary interbed, near contact	-94.7
I-4D	69.2 (227)	CD sedimentary interbed	-219.5
I-5S	30.4 (99.7)	Basalt/BC sedimentary interbed, near contact	-136.6
O-1	29.6 (97)	BC sedimentary interbed, no recovery	-150.9
O-2	32.6 (107)	Basalt/BC sedimentary interbed, near contact	-131.1
O-3	26.8 (88)	Basalt	-257.7
O-3	67.4 (221)	Basalt/CD sedimentary interbed	-97.7
O-4	33.5 (110)	BC sedimentary interbed	-207.9
O-4	69 (226.5)	CD sedimentary interbed	-302.3
O-5	32 (105)	Basalt/BC sedimentary interbed [b]	-141.7
O-7	36.9 (121)	BC sedimentary interbed, no recovery	-189.7[c]
O-7	73.5 (241)	Basalt, rubbly	-26.6 [c]
76-5	6.7 (22)	Sediment-filled fractures	-289.2
76-5	9.4 (31)	AB sedimentary interbed[d]	-266.2
76-5	11.6 (38)	Rubble zone	-171.8
76-5	17.3 (57)	Horizontal fracture with sediment	-64.4
76-5	24.4 (80)	Sediment-filled fractures	-101.0
76-5	29.6 (97)	Moist basalt	-69.4
76-5	31.4 (103)	BC sedimentary interbed	-158.0
77-2	10.0 (32.8)	AB sedimentary interbed,[d] reddish-baked silt	-283.7
77-2	17.1 (56)	Basalt	-130.8
77-2	27.4 (90)	Basalt	-80.4
78-1	10.7 (35)	Fractured basalt, with sediment infilling	-372.7

a. Tensiometers at Wells O1-229, O2-241, O8-229, O6-227 (in bentonite), and 78-1 (25.6 m) (not operational) are excluded from this listing.
b. Discrepancy between the geologist's log and gamma log for Well O-5. Used natural gamma log placement of interbed at 32.2 m.
c. Measurements from February 20, 2003, at 4:00 p.m., because no data exist for February 16, 2003.
d. Sedimentary interbed, not continuous, located approximately 8.4 m bls.

tensiometers in the following discussion. Well names beginning with 'I' (for inside the SDA) and 'O' (for outside the SDA) were drilled and instrumented in 1999 and 2000 as part of the hydrologic characterization activities at the RWMC (Dooley and Higgs 2003). The three remaining wells (i.e., Wells 76-5, 77-2, and 78-1) were drilled and instrumented before 1999. A nested series of advanced tensiometers were installed in Well 76-5 in June 1996 (Sisson and Hubbell 1999). Wells 77-2 and 78-1 were instrumented with advanced tensiometers in December 1995, with the addition of a portable tensiometer at the bottom of Well 77-2 in December 1999 (Hubbell and Sisson 1996).

Tensiometers in the I- and O-series wells were installed in a silica-flour slurry that was placed around the porous cup to obtain a hydraulic connection between the cup and the geologic formation (Dooley and Higgs 2003). The height of the silica flour slurry interval ranged from 1–4 m. Borehole diameters at instrumentation depth were 9.6 cm in the I-series wells (with the exception of Well I-5S, which was 25.1 cm) and 25.1 cm in the O-series wells. Granular bentonite was used to seal the remainder of the borehole between the instrumented depths. At two of the wells (i.e., Wells I-3D and I-4S), a silica sand interval (12.2 and 7.6 m, respectively) was placed above the silica flour interval. The BC and CD sedimentary interbeds (at approximately 34 and 73 m) were generally targeted for tensiometer placement, although some instruments were placed adjacent to basalt.

Installation methods for tensiometers in Wells 76-5, 77-2, and 78-1 differed from the methods used for the I- and O-series wells. At Well 76-5, the porous cups of the tensiometers were placed in a 0.3-1-m layer of silt loam (15.2-cm diameter borehole) to hydraulically connect the porous cup to the fractured basalt (Hubbell et al. 2002). Granular bentonite (about 0.3-m) layers were placed above and beneath the loam-filled monitoring depths to isolate the monitoring intervals. Coarse sand (2.4–3.3 mm) filled the remaining portions of the borehole between the tensiometer monitoring depths with thin layers of bentonite placed about every 2 m to inhibit moisture flow through the borehole. Tensiometers in Wells 77-2 and 78-1 were placed in dry native fill (loam), and bentonite layers were placed between instrumented depths to isolate each instrumented depth. The porous cups of these tensiometers were placed in a 1.8-m dry loam layer (Well 77-2, 12.4-cm diameter borehole) and in a 0.6–0.7-m dry loam layer (Well 78-1, 7.62-cm diameter borehole).

4. RESULTS AND DISCUSSION

Water-potential data over time for each borehole are shown in Figures 5 through 8 for spring 2000 through September 2003. Additionally, water-potential values at each location for February 16, 2003, are listed in Table 1. Data in Figures 5 through 8 are grouped by depth, lithology, and steady state versus trending water-potential data. Water potentials in basalt and sediments above 17 m are shown in Figure 5. Locations below 17 m exhibiting steady-state conditions are shown in Figure 6. Locations below 17 m exhibiting long-term trends over the 3-1/2-year period are shown in Figure 7, and data from Well I5S-30 are shown in Figure 8.

In general, water potentials ranged from a near-saturated -30 cm of water to approximately -375 cm of water. Data gaps in water-potential profiles were due to equipment malfunctions (e.g., battery or transducer failure) or loss of water from the tensiometer cup. Data spikes caused by the short-term influence of nearby suction lysimeter sampling (McElroy and Hubbell 2003), as shown in Figure 6(b) at Well I1S-31, were removed from some of the data in Figures 6(a) and (b) to simplify data presentation.

The advanced tensiometer data may be affected by equipment drift, barometric pressure fluctuations, and changes in the length of the hanging water column (less than 15 cm of water) from air entry into the water chamber. The type of backfill used to complete the well may also influence data. Using fine-grained backfill over an approximate 1.5-m interval provides a composite measurement and may dampen infiltration and drainage. The influence of the dampened response is lessened by the small temporal changes evidenced in the ambient water potential.

Tensiometric data presented in Figures 5 through 8 are believed to represent equilibrated ambient conditions, with the possible exception of Well 05-32. Two-month equilibration times were observed in well completions using dry backfill at Wells 76-5, 77-2, and 78-1 (Hubbell et al. 2002; McElroy and Hubbell 2003). Sisson, Schafer, and Hubbell (2000) found that wet backfill equilibrated much more rapidly (days) than dry backfill. Wet backfill was used at the I- and O- series wells to reduce equilibration times, and data collection did not begin for 1–6 months after the boreholes were backfilled.

4.1 Temporal Trends

Water potentials from FY 2003 were evaluated for temporal trends. When analyzing the temporal response of a single tensiometer, the higher (or less negative) the water-potential measurement, the greater the wetness of that medium. Increasing water potentials over time indicate wetting of the medium, and conversely, decreasing water potentials indicate drying of the medium over time. Positive water potentials indicate saturated conditions, while negative water potentials indicate unsaturated conditions.

Water potentials that do not change over time suggest steady-state conditions, implying a constant water flux. Steady state is relative to the monitored period; some long-term changes in water potentials may not be large enough to discern over the 3-1/2-year period. These long-term changes may become more evident as the monitoring period is extended. Transient conditions imply changes in moisture over time, presumably from changes in infiltration at land surface. Specific recharge events over short time periods (e.g., from snowmelt and run-off) are easily identified because of the large changes in water potentials. Small changes in water potentials over long time frames are more difficult to discern. These long-term-transient trends are arbitrarily defined in this report by the presence of a long-term shift in water potentials of more than 15 cm of water.

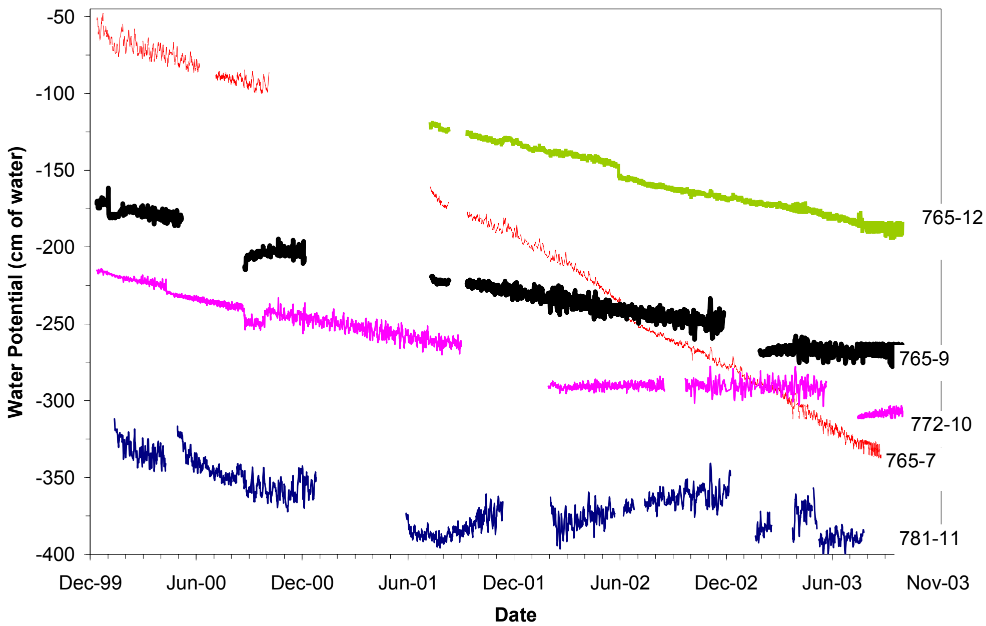


Figure 5. Long-term drying trends at advanced tensiometer locations above depths of 17 m.

Fiscal-Year 2003 data from advanced tensiometers above depths of 17 m (see Figure 5) showed decreasing water potentials at Wells 765-7, 765-9, 765-12, 772-10, and 78-11, continuing the long-term drying trends identified at these depths in McElroy and Hubbell (2003). Overall decreases (spring 2000 through September 2003) ranged from approximately 60 cm of water at Wells 781-11, 765-9, and 76-12 to approximately 275 cm of water at Well 765-7. The tensiometers indicate the drying has slowed, and later portions of the FY 2003 data (except Well 765-7) suggest conditions may be approaching steady state. The tensiometer at Well 78-11 is operating at close to maximum range, and the resulting loss of water from the porous cup caused the slow rise in water potentials in the summer of 2001 and most of 2002. Adding water to the reservoir reset the tensiometer and lowered the water potential.

Low precipitation over the last few years may have been a factor in the decreased water potentials at these shallow (less than 17-m) depths (McElroy and Hubbell 2003). Figure 9 shows the annual precipitation (October through September) since 1991 at the INEEL Central Facilities Area (NOAA 2003), located approximately 8 km northeast of the RWMC. Annual precipitation has decreased to less than 14 cm for the past 4 years (2000, 2001, 2002, and 2003), which is less than the average annual precipitation of 22 cm/year (Clawson, Start, and Ricks 1989). Water potentials at each of the locations above 17 m, with the exception of Well 765-12, have decreased to less than the steady-state values found before 1999 (McElroy and Hubbell 2003). The shallower (less than 17 m) sediments and basalts are likely responding to decreased surface infiltration.

Below 17 m, FY 2003 water potential temporal trends varied. Fifteen of the 25 deep locations continued to indicate steady-state conditions (see Figure 6), as identified in the 2000 through August 2002 data (McElroy and Hubbell 2003). Fiscal Year 2003 water potentials were stable in basalt at Wells 772-17, 772-27, 765-24, 765-30, I2D-54, O3-27, and O7-74 (see Figure 6[a]); in the BC sedimentary interbed (see Figure 6[b]) at Wells 765-31, I1S-31, I2S-29, O2-33, O5-32, and O7-37; and in the CD sedimentary interbed (see Figure 6[c]) at Wells I2D-68 and O3-67. The two data spikes at Well 772-27 (see Figure 6[a]), in March 2001 and December 2002 were recorded by a portable tensiometer in an open standpipe and appear to have been artificially induced by condensation that

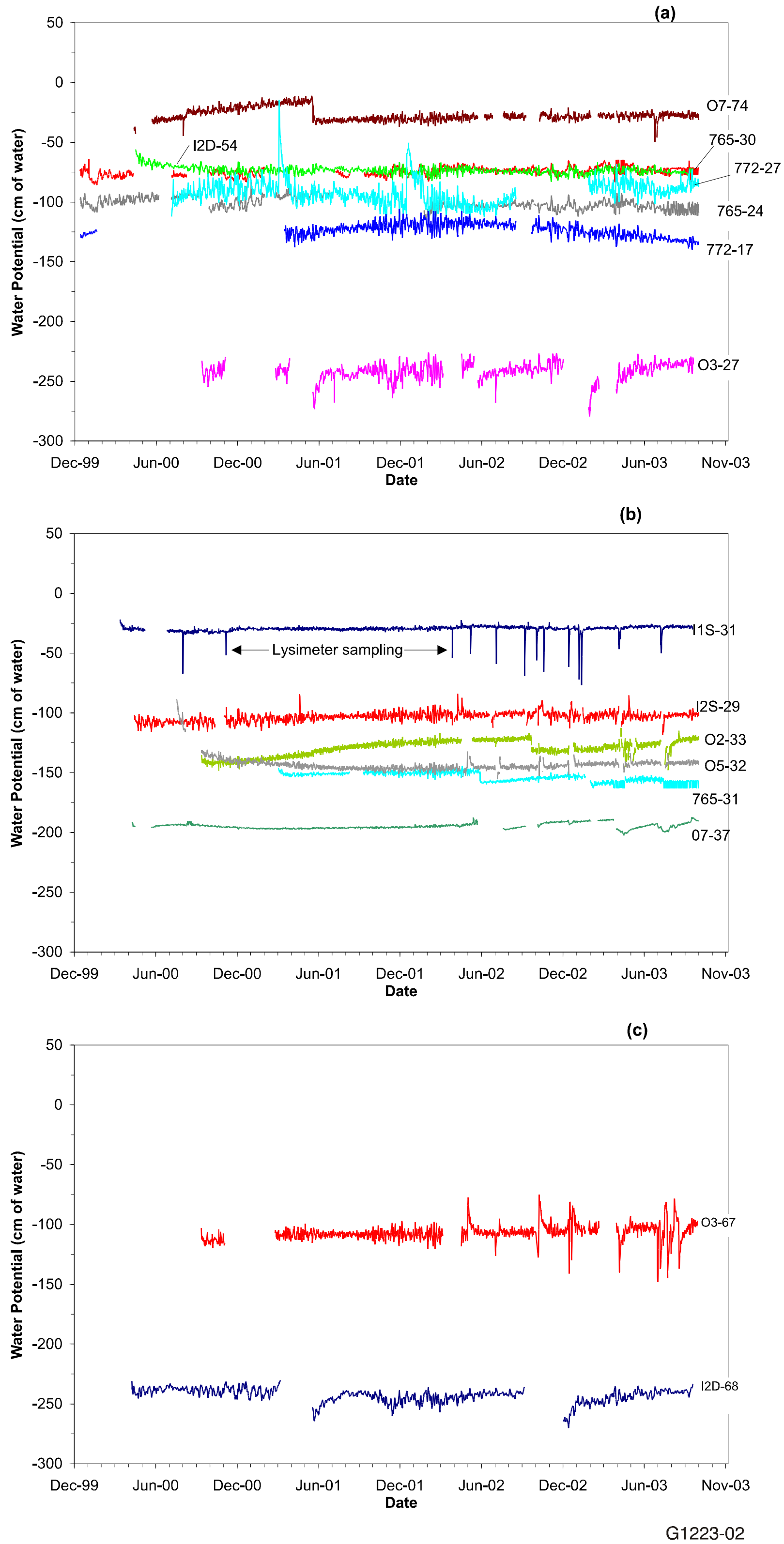


Figure 6. Stable moisture contents indicating steady-state conditions in the (a) basalt, at or below 17 m, (b) BC sedimentary interbed, and (c) CD sedimentary interbed.

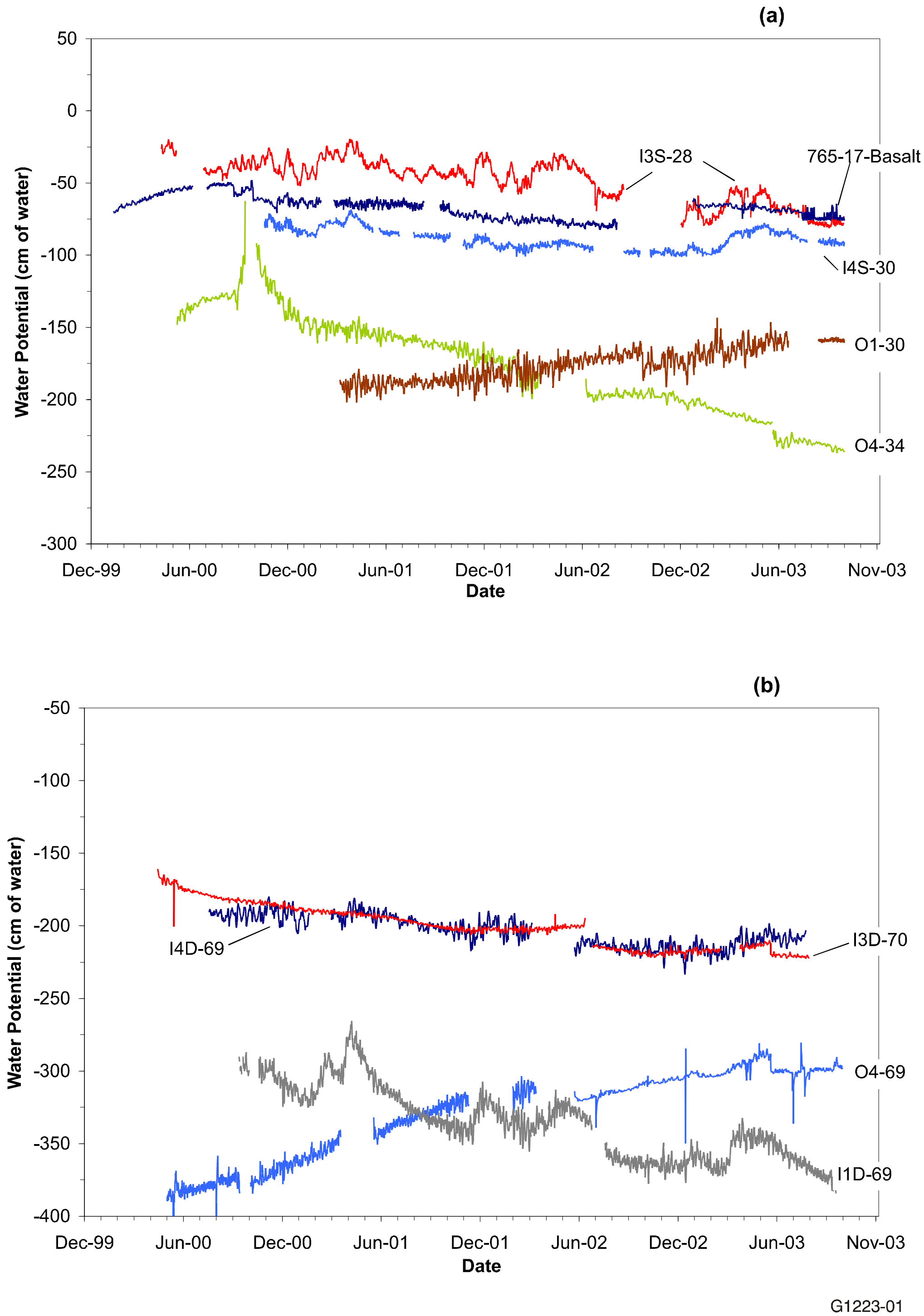


Figure 7. Long-term wetting and drying trends below 17 m in the (a) BC sedimentary interbed and basalt, and the (b) CD sedimentary interbed.

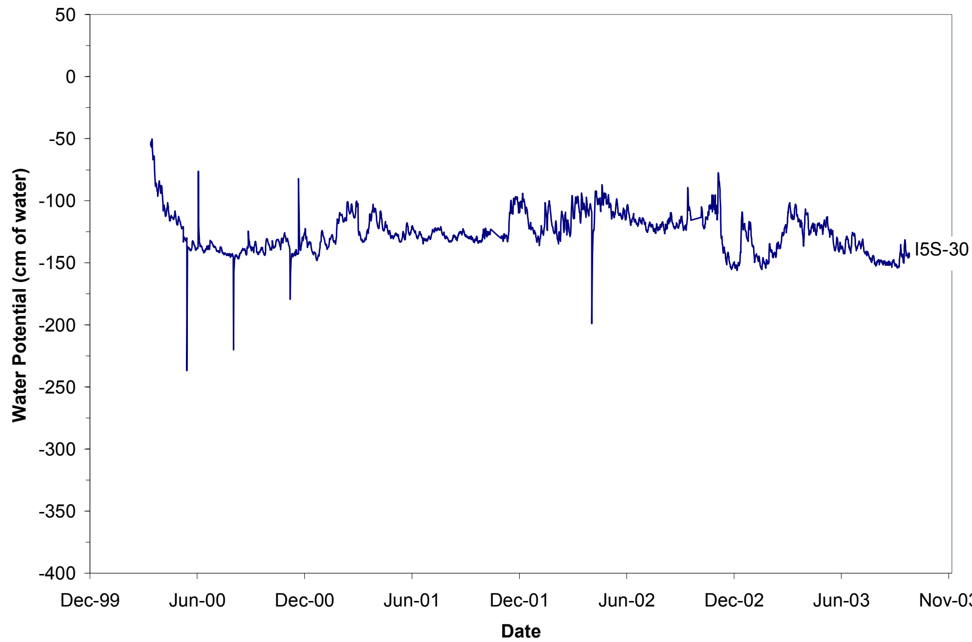


Figure 8. Water-potential data from Well I5S-30.

quickly dissipates (McElroy and Hubbell 2003). The slow rise in water-potential values at Wells O2-33 (see Figure 6[b]) and O7-74 (see Figure 6[a]) is indicative of air entry into the tensiometer. Refilling the water chamber with water returned the measurements to near the initial readings.

In FY 2003, long-term drying trends were observed at seven of the 25 deep locations. Water-potential decreases continued to be observed in the basalt at Well 765-17 (see Figure 7[a]), in BC interbed sediments at Wells I3S-28, I4S-30 (until December 2002), and O4-34 (see Figure 7[a]), and in the CD interbed sediments at Wells I1D-69, I3D-70, and I4D-69 (until March 2003, see Figure 7[b]). The decreasing water potentials at Wells 765-17 and O4-34 follow recharge events recorded in September and October 2000, respectively. At Well 765-17, the 7-cm offset (increase) in water potentials in late 2002 is the result of replacing the transducer, but the trend of decreasing water potentials continued. The cyclic rise and decline in water potentials (high frequency oscillations) that are most prominent in Wells I3S-28 and I1D-69, but also occur in Wells I4S-30 and I4D-69, appear to be related to barometric fluctuations. It is possible that these fluctuations are related to infiltration and drainage; however, no clear distinction can be drawn at this time. Water potential decreases at these seven locations, from 2000 through September 2003, ranged from an overall decrease of approximately 16 cm at Well I4S-30 to a more substantial decrease of approximately -105 cm at Well O4-34.

Several different mechanisms might result in the observed drying trends at depth. McElroy and Hubbell (2003) suggest the long-term drying trends are the result of decreased surface recharge in the SDA from recent years of less-than-average precipitation. The wells that reflect drying trends (except for Wells 76-5 and O-4) are located along the main east-west drainage ditch that runs through the center of the SDA. These ditches collect surface water from surrounding areas and focus run-off and infiltration along the road. Sedimentary interbeds and basalt beneath those areas of focused infiltration may be responding to decreased run-off from 4 years of less-than-average precipitation (2000 through 2003). Development of this hypothesis is limited by the lack of wells sited away from drainage ditches in the SDA and by the need for nested tensiometers near the ditches to track surface recharge.

Another possible mechanism cited by McElroy and Hubbell (2003) for the observed drying trends is drainage following lateral underflow from the spreading areas west and south of the SDA (see Figure 1) into the sedimentary interbeds beneath the SDA. The last discharge to the spreading areas occurred in 1999, a year before the start of the advanced tensiometer monitoring. Monitoring during periods of discharge to the spreading areas, with nested advanced tensiometers that monitor a vertical profile, would be needed to fully evaluate the influence of lateral flow from the spreading areas.

Two tensiometers, at Wells O1-30, and O4-69, showed gradual wetting trends over the 3-1/2-year monitoring period. The tensiometer at Well O1-30 was previously indeterminate (McElroy and Hubbell 2003), but addition of the FY 2003 data indicate a slow, approximately 30 cm of water rise in water potentials since spring 2000. In the CD sedimentary interbed at Well O4-69 (see Figure 7[b]), water potentials in FY 2003 continued to rise until approximately May 2003, when the rise appeared to slow and stabilize, resulting in a rise of approximately 90 cm of water over the 3-1/2-year monitoring period. The increase in water potentials at Well O4-69 occurred over the same time as the drying of sediments in the shallower BC interbed (Well O4-34) at the same well, and are likely related.

The FY 2003 data indicate a water-potential increase in March 2003 at Wells I3S-28, 1D-69, I4S-30, I5S-30, and I4D-69 (see Figures 7 and 8). The increase in water potentials may be the result of barometric pressure influences, which these wells appear to have previously exhibited (McElroy and Hubbell 2003), or possibly recharge. Barometric pressure influence on water potential data was

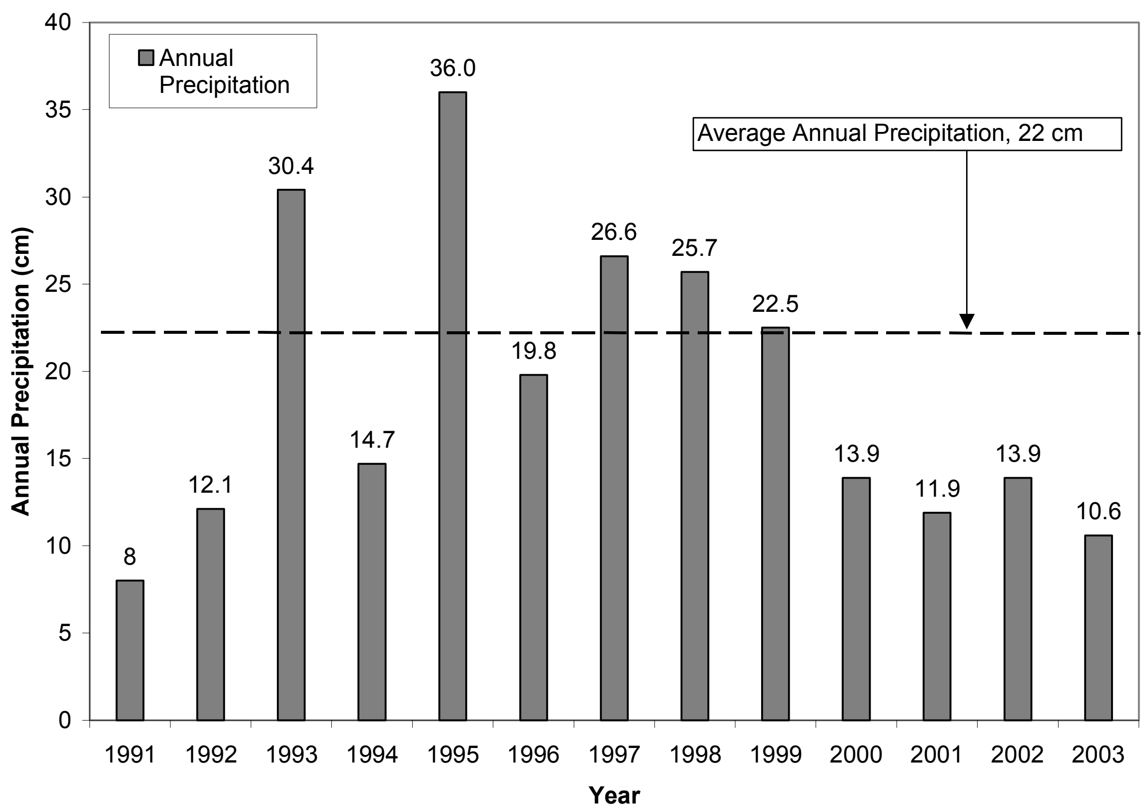


Figure 9. Precipitation at the Central Facilities Area for each water year (i.e., October through September) since 1993.

investigated at Well I5S-30, and results showed that residual water potential and (negative) barometric pressure exhibited a high temporal cross correlation at a 1-day lag. Water potential was modeled with an autoregressive model with one parameter while the barometric pressure was modeled with an autoregressive model with nine lag parameters. The residuals from both models were temporally independent and exhibited no trend or cyclic pattern (e.g., white noise). Figure 10 shows a subset of the residuals of both models plotted at a 1-day lag. The cross correlation of the residuals at a 1-day lag was significantly greater than zero and high (r = 0.6). The high correlation indicates daily variations in water potentials at Well I5S are closely related to negative barometric pressure from the day before. A similar analysis should be performed on the remaining wells that appear to have barometric fluctuations (i.e., Wells I1D-69, I3S-28, I4S30, and I4D-69) to determine the timing and influence of barometric pressure on water potentials and to help develop a method of removing that influence for further analyses.

The addition of FY 2003 data did not clarify any moisture trends at Well I5S-30 (see Figure 10). Temporal data could not be clearly characterized as either steady state or showing a long-term trend because of large variations in water potentials that appear to be related to barometric fluctuations.

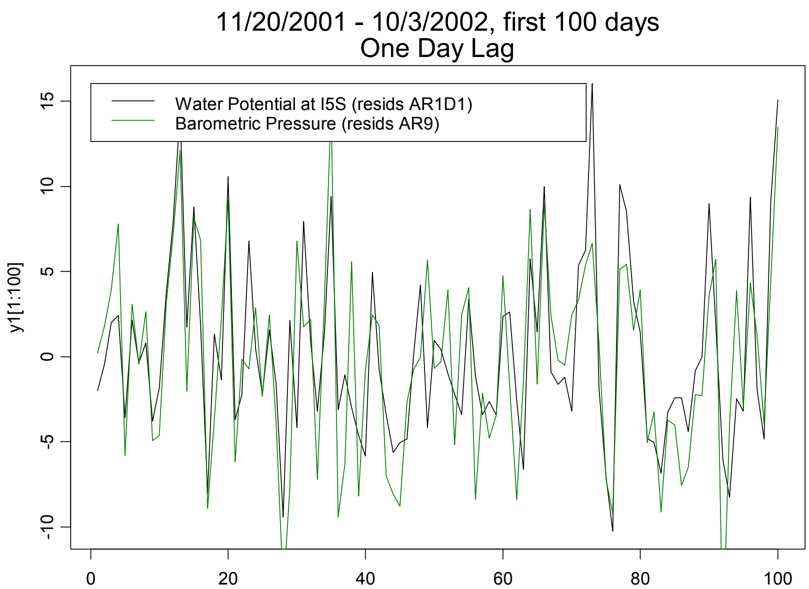


Figure 10. Subset of residuals of both models plotted at a 1-day lag from Well I5S-30.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The advanced tensiometer network provides in situ, continuous, water-potential data that give a large-scale picture of the deep moisture system at the RWMC. Data collection from advanced tensiometers at the RWMC are currently providing baseline water-potential data from sedimentary interbeds and basalts that can be used to help assess the remediation and closure of the SDA and can be used for hydrologic flow model calibration and prediction. The data acquired by the advanced tensiometers are also establishing baseline conditions that can be used to assess lateral flow from the spreading areas in the future.

In this report, water-potential data collected from the deep tensiometer network during FY 2003 were added to the previously published data and evaluated.

Water-potential data from the majority of the deepest (17 m or deeper) advanced tensiometer locations continued to indicate little-to-no change in moisture, suggesting steady-state conditions existed at those locations over the past 3-1/2-year monitoring period.

Long-term drying trends were noted in some sediments and basalts. The largest overall decrease in water potentials occurred in the shallower sediments and basalts above the 17-m depth. These shallower depths may be responding to decreased infiltration at the surface from the cumulative effect of less-than-average annual precipitation for the last 4 years (2000 through 2003).

In the deeper sediments, long-term drying continued in the BC interbed sediments at Wells I3S-28, I4S-30, and O4-34 and in the CD interbed sediments at Wells I1D-69, I3D-70, and I4D-69. Wells showing long-term drying trends are those located nearest the drainage ditches that parallel the main east-west road through the SDA. These drainage ditches likely focused surface infiltration during years of high run-off from snowmelt. The long-term drying trends in sediments at wells near these drainage ditches may be in response to decreased run-off from 4 years of less-than-average precipitation (2000 through 2003.

Two deep tensiometer locations, Wells O1-30 and O4-69, showed gradual wetting trends over the 3-1/2-year-monitoring period. The tensiometer at Well O1-30 was previously indeterminate, but the addition of the FY 2003 data indicated a slow approximately 30 cm of water rise in water potentials since spring 2000. In the CD sedimentary interbed at Well O4-69, the increase in water potentials occurred over the same time frame as the drying of sediments in the shallower BC interbed (Well O4-34) at the same well, and appeared to be related.

The advanced tensiometer monitoring is recording in situ water-potential data in the deep subsurface that should remain part of the long-term monitoring strategy at the SDA. These data provide a monitoring reference and baseline to help assess the remediation and future closure of the SDA.

5.2 Recommendations

The following recommendations are suggested for the deep advanced tensiometer network:

- **Continue to monitor deep advanced tensiometers** to determine subsurface response to infiltration and potential effects of lateral flow from the spreading areas to the SDA. Locations of advanced tensiometers in the I- and O-series wells were chosen, in part, to determine subsurface response to surface infiltration and the effects of lateral flow from the spreading areas to the SDA. However, monitoring coincided with below-normal precipitation for the last 4 years (2000 through 2003) and lack of water in the spreading areas. Monitoring is needed during normal and above-normal precipitation years, as well as during periods of discharge to the spreading areas. This continued monitoring is necessary to establish baseline conditions before emplacement of any infiltration-reducing cap at the SDA.

- **Perform a time-series analysis on water-potential data** from Wells I1D-69, I3S-28, I4S-30, and I4D-69 to determine the timing and influence of barometric pressure on water potentials and develop a method of removing that influence. This is needed to evaluate possible infiltration and drainage at these locations.

- **Instrument a series of wells with nested advanced tensiometers.** The monitoring data from the advanced tensiometer network have improved the conceptual understanding of the movement of water through the subsurface beneath the SDA. While some general behaviors are evident, (e.g., wetter conditions inside the SDA compared to outside the SDA for the BC sedimentary interbed), there is also evidence of complex preferential pathways. To demonstrate ability to monitor contaminant movement in the vadose zone, consideration should be given to expanding the advanced tensiometer network to include a series of wells instrumented with nested advanced tensiometers.

- **Include FY 2002 hydraulic property data** in deep infiltration assessments and advanced tensiometer data evaluations. This will require development and documentation of representative moisture characteristic curves that incorporate the FY 2002 data.

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